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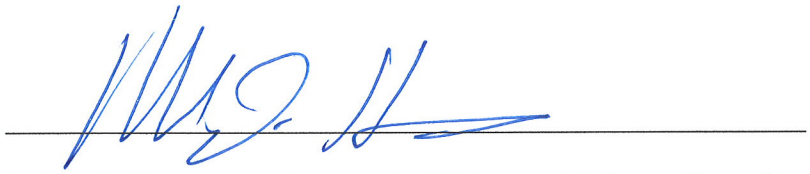
Transmittal to Basin and Bay Area Stakeholders Committees (BBASCs) and
Basin and Bay Expert Science Teams (BBESTs)

Discussion Paper: Moving from Instream Flow Regime Matrix Development to Environmental Flow Standard Recommendations

During 2009, the SB3 Texas Environmental Flows Science Advisory Committee (SAC) prepared several guidance documents for the BBESTs to consider in their development of environmental flow regime recommendations. Specifically, with respect to the instream flow component of the flow regime, the SAC provided information on hydrology-based environmental flow methodology, geographic scope, and biological, water quality and sediment transport overlays on the hydrology-based results. The two BBEST groups that have produced their final reports (Trinity/San Jacinto and Sabine/Neches basins) both depended, at least in large measure, upon the environmental flow matrix generated by the Hydrology-Based Environmental Flow Regime (HEFR) model.

The BBASCs are now charged with the task of developing environmental flow standards and strategies for implementing these standards. In doing so, they are to consider the science-based recommendations of their respective BBEST.

There are several issues related to the implementation of the BBEST instream environmental flow regime. The SAC has prepared the attached Discussion Paper to assist the stakeholders in their consideration of the BBEST analyses. As noted, the SAC will continue to explore these issues and approaches as the SB3 process proceeds westward across the state. As always, your feedback would be welcome.



Robert J. Huston, Chairman, SB3 Science Advisory Committee

Discussion Paper: Moving from Instream Flow Regime Matrix Development to Environmental Flow Standard Recommendations

Introduction

As the work of the Basin and Bay Expert Science Teams (BBESTs) and the Basin and Bay Area Stakeholders Committees (BBASCs) proceeds pursuant to the mandates of Senate Bill 3, the Science Advisory Committee (SAC) has identified a number of issues associated with how the instream flow matrix generated by the Hydrology-based Environmental Flow Regime (HEFR) model [SAC, 2009a][1] or other methods may be translated into a recommended environmental flow regime at the BBEST level; and subsequently, how that environmental flow analysis and recommended flow regime can be used by the stakeholder groups to develop recommendations for environmental flow standards and strategies, as required by Senate Bill 3. This document is intended to (1) outline the general procedural steps and responsibilities, (2) clarify and discuss technical issues, and (3) offer some suggestions for implementation. It also might serve as a resource for members of the BBASC who are new to the issues of environmental flows. This document should be considered a work in progress, as the SAC is just beginning to explore these issues and because approaches that may be appropriate for the relatively more water-rich basins in the eastern part of the state may not always be appropriate as the Senate Bill 3 process moves west. Moreover, while this document offers some interpretation of the purpose and desired outcomes of various steps in the Senate Bill 3 process, the SAC does not intend, nor is it charged with, offering a legal interpretation of legislative language or its intent.

The Senate Bill 3 Process

Senate Bill 3 (SB 3) outlines a systematic process for developing and establishing requirements for environmental flows for the basin and bay systems of the state. For each basin and bay system:

- SB 3 requires each BBEST to develop environmental flow analyses and a recommended environmental flow regime(s) using best available science. The statute defines these terms as follows:
    - Environmental flow analysis: "the application of a scientifically derived process for predicting the response of an ecosystem to changes in instream flows or freshwater flows."
    - Environmental flow regime: "a schedule of flow quantities that reflects seasonal and yearly fluctuations that typically would vary geographically, by specific location in a watershed, and that are shown to be adequate to support a sound ecological environment and to maintain the

[1] References are listed at the end of this document.

productivity, extent, and persistence of key aquatic habitats in and along the affected water bodies."

The statute's prescription for the BBEST is clear. Their work is to focus solely on maintenance of key aquatic habitats and specification of flows that are considered necessary to support a "sound ecological environment." Hence, the product of the BBEST's efforts strives to reflect only the environmental flow needs, and does not consider other uses for the flows, including human needs. The BBEST's "environmental-focused" recommendations maintain their integrity through the remainder of the SB 3 process. As this paper will discuss, however, BBEST collaborative input and opinion on BBASC recommended flow standards, which may not fully adopt the BBEST flow regime recommendations, could be an important element to meeting the full SB3 objectives.

- SB 3 further requires that the BBASC review the environmental flow analyses and environmental flow regime recommendations from the BBEST and consider them, along with other factors including "the present and future needs for water for other uses related to water supply planning." Based on these deliberations, the BBASC is to develop recommendations regarding "environmental flow standards and strategies to meet the environmental flow standards...". "Environmental flow standards", under Sec. 11.1471, are to be "appropriate" for each basin and bay system and be "adequate to support a sound ecological environment, to the maximum extent reasonable considering other public interests and other relevant factors."

The flow standards developed by the BBASC will likely be based on an environmental flow regime, but it does not have to be identical to the product of the BBEST. For example, an overbank flow may be an important part of a flow regime but not included as part of the standard in some segments of the basin due to concerns associated with flooding and liability. Present and future needs for water for other uses related to water supply planning or economic impacts may dictate that a recommended or adopted flow standard not conform to a particular flow regime.

- The BBEST and BBASC recommendations are transmitted to the Texas Commission on Environmental Quality (TCEQ), which is charged with adopting, by rule, appropriate environmental flow standards "that are adequate to support a sound ecological environment, to the maximum extent reasonable considering other public interests and other relevant factors".

In addition to the BBEST and BBASC recommendations, the TCEQ is to consider comments from the Environmental Flows Advisory Group (EFAG) on the BBEST recommendations, other public comments, the specific extent and characteristics of the basin and bay system being evaluated, economic factors, human and other competing water needs in the basin and bay system, and information provided by the SAC. TCEQ is also directed to establish an amount of unappropriated water, if available, to be set aside to ensure "to the maximum extent reasonable when considering human water needs" that the ability to satisfy environmental flow standards will not be impaired by future permits when and if they are issued and in place.

Instream Flow Regime Matrix Development

There appears to be general agreement among aquatic biologists and ecologists that the flow requirements necessary to support a sound ecological environment in a stream system should consist of several flow

components with characteristic seasonality. Following guidance from the National Research Council, the Senate Bill 2 Texas Instream Flow Program (TIFP) [TCEQ *et al*, 2008] uses the following structure to describe an environmental flow regime:

- minimum *subsistence flows* to maintain water quality criteria and prevent loss of aquatic organisms due to, for example, lethal high temperatures, low dissolved oxygen levels or loss of critical habitats;
- *base flows* representing the range of "average" or "normal" flow conditions in the absence of significant precipitation or runoff events that provide instream habitat conditions needed to maintain the diversity of habitats and resources that support native aquatic and riparian species;
- short duration, high magnitude, in-channel *high flow pulses* that occur during or immediately following rainfall events and provide spawning cues and transport of eggs and larvae of fishes and aquatic invertebrates, as well as helping to maintain important physical habitat features and connectivity along a stream channel
- *overbank flows* consisting of infrequent, high magnitude flow events that produce water levels that exceed channel banks and result in water entering the floodplain to maintain riparian habitat

The SAC also recommended this same structure in order to maximize consistency in the framework of environmental flow recommendations in Texas [SAC, 2009a].

A framework for displaying the TIFP components in the form of a "flow regime matrix" is shown in Figure 1. The daily flow record for a specific historical period is conceived to be sorted into the four TIFP component flows, and the data sets for each of these are further sorted into time-period categories before being subjected to statistical analyses. By "time-period categories" is meant some subdivision of the calendar year, e.g., season, month, or user-defined periods of possibly different lengths. The fact that the number and length of these calendar periods are discretionary and at the disposal of the user is emphasized in Figure 1 by the nonspecific terms *season*, *period*, *bin*, and *span*. A different time-period term is assigned to each flow component to emphasize that the user may choose to define distinct calendar periods for each flow component. For example, the rare overbank flows might be evaluated on an annual basis, the high-flow pulses on a semiannual basis (loosely, the "spring" pulses and the "fall" pulses), base flows on a monthly or seasonal basis to display the seasonal variation in streamflow, and subsistence flows on an annual basis. With an eye to potential application in flow management, some workers have indicated the potential utility of separate flow specification based upon whether prevailing conditions are "wet", "dry", or "normal." These conditions might be based upon independent evaluations of meteorological data, upon operational parameters such as the level of storage in a reservoir, or upon the level of flow itself. Figure 1 displays these three generic categories, to conceptually accommodate this level of flow specification.

Depiction is conceived to be statistical. The lower-magnitude flows – base flows and subsistence flows in particular – could be represented as flow values at a specified frequency, frequencies at specified flow, or other statistical parameters, as required for evaluation of the flow time series in light of relationships between flow and the stream ecosystem that might be indicated by scientific studies of the riverine environment. Lacking such scientific results, the user may specify standard frequency or flow magnitude levels, such as decile points on the frequency distribution, or integral-year return periods for high-flow pulses, together with standard time periods, such as months, to obtain a statistical analysis of the flow

time series. The resulting flow matrix based entirely upon historical flow variation would serve as a "default" analysis, pending availability of specific scientific data on the response of the ecosystem to flows.

The HEFR model provides a calculation tool that determines magnitudes for the various environmental flow components, based on a specified historical daily flow record and user input regarding desired flow characteristics. Output from HEFR is in the format of a "flow matrix," or array, which in fact provided the pattern for the generic depiction of Figure 1. HEFR includes the capability to separate and identify a sequence of daily flows as an "event" for purposes of analyzing the overbank and flood pulse component flows. The statistics of these events are then quantified by return frequency, peak flow, duration, etc., following the usual conventions of hydrology. While the user has a wide range of options for the computed products of HEFR, HEFR does not yet have the full generality indicated by Figure 1. For example, in the present HEFR version, the same seasonal definition is used for all flow components, so to obtain results for different time periods applicable to individual components, multiple runs would be necessary. At present the user has no control within HEFR to employ separate statistical evaluations for the defined "wet", "dry" and "average" flow conditions. The default option for HEFR is a flow matrix in which wet, dry and average years are defined *post facto* by quartile points on the frequency distribution. The quartile-frequency magnitudes are chosen mainly for numerical convenience (because 25 divides evenly into 100), and have no physical or ecological significance. While this default flow matrix, or a similar statistical depiction based only on the hydrological record, may represent a starting point for environmental flow analyses, it must be remembered that the matrix is based on little or no consideration of the actual flow requirements for specific aquatic organisms.

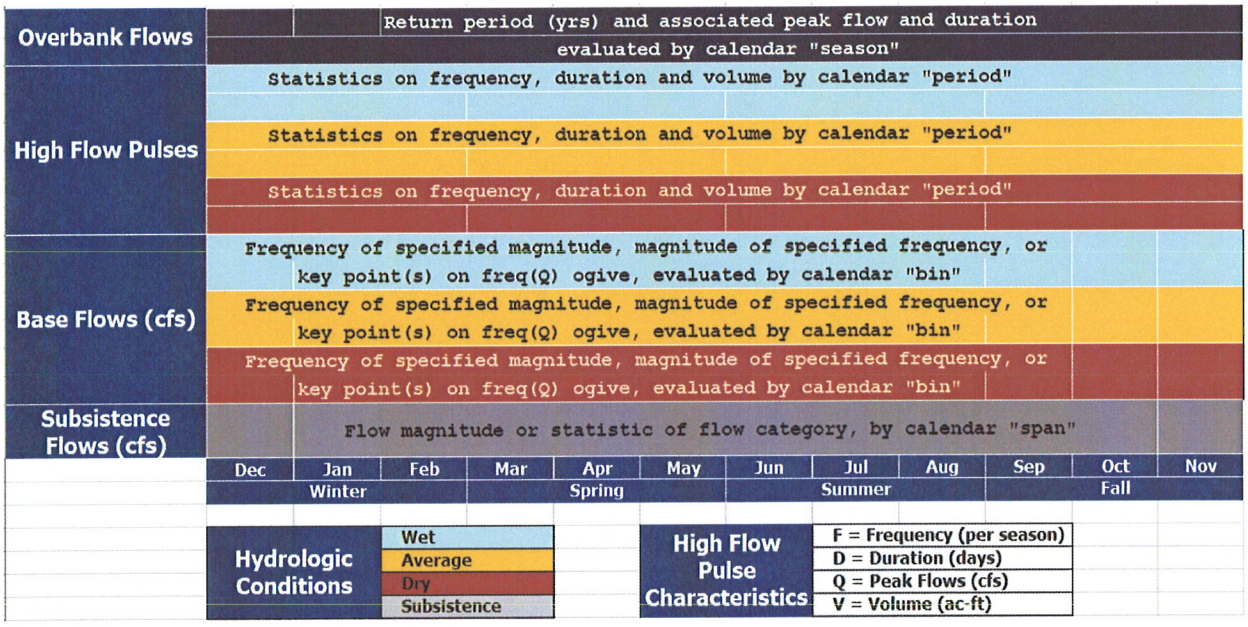


Figure 1 –Instream Flow Regime Matrix

While aspects of historical hydrologic conditions may form the initial basis for establishing instream environmental flow requirements by the BBESTs, consideration is also given to applying information from other disciplines with regard to environmental flow needs, where this information is available. This

includes information pertaining to aquatic biology, water quality and nutrients, and fluvial sediment transport. For example, special flow needs may be required to assure that the essential elements for maintaining suitable habitat conditions, including primary productivity, are provided to support particular aquatic species; or certain subsistence flows may be needed during certain times of the year to maintain minimum dissolved oxygen levels that are known to be critical for specific organisms. The existing erosional and depositional processes that influence channel stability and geomorphology also could be affected by a proposed environmental flow regime, which may or may not result in a change to an existing sound ecological environment. For example, a particular water development project with stipulated instream environmental flow requirements could alter flow conditions enough to cause the existing channel to be reconfigured for some distance downstream, but such altered channel conditions may (or may not) still support a sound ecological environment. During the initial phase of establishing environmental flow regime recommendations, it is likely that a certain degree of subjectivity and professional judgment will be necessary to address how each of these disciplines influences the environmental flow regime recommendations, with the goal still being the development of the environmental flow conditions necessary to support a sound ecological environment.

During the course of its deliberations to develop environmental flow recommendations, the BBEST may find it useful, or maybe even necessary, to translate a particular instream flow regime, or a set of instream flow regimes, into continuous time-series hydrographs at downstream locations. Such time series hydrographs are important for evaluating achievement of attainment guidelines and potentially to facilitate one or more of the overlay processes (biology [SAC, 2009b], water quality [SAC, 2009c], or sediment [SAC, 2009d]). Information from these overlays would be expected to help (re)define the required flow regime (in an iterative sense: define a preliminary flow regime → develop time series hydrographs → evaluate using overlays → redefine flow regime → continue loop). Such time-series hydrographs also could provide insight into potential effects on existing erosional and depositional processes that influence sediment transport and eventually channel stability and geomorphology, and they may be essential for evaluating the impacts of a set of instream environmental flow regimes on the magnitude and timing of freshwater inflows to a downstream estuarine system.

If such time-series hydrographs are to be developed, then an assumption must be made as to what condition of future water development, i.e., water development infrastructure, is to be utilized. *Infrastructure*, in this context, is an assumed condition of future annual diversion and/or reservoir storage capacity that is defined for a particular watercourse or an entire river basin for the purpose of evaluating the effect of certain environmental flow restrictions designed specifically to ensure that the new water use activity does not impair the ability to satisfy a proposed environmental flow regime(s) or standard(s). It must be recognized that assumptions about future water demands, including potential future water development infrastructure, for purposes of developing recommended environmental flow standards is fundamentally the province of the BBASC, and not the BBEST. Therefore, should the BBEST find it necessary to take this step in order to understand and refine its flow regime recommendations, it must be stressed that any future infrastructure assumptions are just that – *assumptions* – and are not to be viewed as supplanting the province of the BBASC to introduce future conditions into their standards deliberations.

Example infrastructure options that could be used by the BBEST include (1) surface water development projects as identified and considered in the State's ongoing regional water supply planning program, which currently is embodied in the TWDB's 2007 State Water Plan, or (2) some other assumed

infrastructure condition considered reasonable and appropriate for the evaluation of the impacts of specified instream environmental flow requirements. Most, if not all, of the proposed major surface water development projects in the 2007 State Water Plan already have been represented in the water availability models (WAMs) for river basins across the state through the regional planning process[2], although none with any of the environmental flow requirements that are likely to emerge from the BBEST analyses (which would have to be added). Still, the means readily exist, using the Water Rights Analysis Package (WRAP) and the WAM datasets to perform at least the initial evaluation of the adequacy of proposed environmental flow requirements when considering future flow characteristics with implementation of various potential future water development projects.

It is important to note that if the WAM datasets are to be employed by the BBESTs, or the BBASCs, as part of their analyses of environmental flows, there are certain aspects of the WRAP program, as it exists today, that may limit the ability to effectively represent the types of environmental flow restrictions that are likely to emerge from the SB3 process. These have to do primarily with the monthly time step that is used in WRAP to perform the water availability simulations. Application of WRAP with a monthly time step reduces daily flow variations to average monthly flow quantities and requires that environmental flow restrictions also be expressed as monthly flow quantities. Constant flow requirements, such as subsistence and base flows, can be effectively represented using WRAP and the WAM datasets; although, their intra-monthly application to daily varying flows can be somewhat limited. Certainly, with a one-month time step, it is difficult to effectively account for multi-day high-flow pulse or overbanking flood events in the simulations. The development of methods to approximate episodic flow requirements and refinements to WRAP to better accommodate episodic events are in progress by the TCEQ and its consultants. At this time, use of WRAP with a monthly time step may result in only an approximation of environmental flow restrictions in water availability modeling and may potentially produce simulated flows that are not fully representative of actual conditions.

One option that has been discussed for translating a particular instream flow regime, or a set of instream flow regimes, into a continuous time-series hydrograph is to consider the "maximum diversion/ impoundment" scenario whereby the only flow remaining in a stream or passing into a coastal bay after application of a particular set of environmental flow requirements is the environmental flow prescription itself. In other words, all other streamflow would be fully diverted and/or impounded by water development projects, either existing or future. For the eastern basins, notably the Sabine/Neches and Trinity/San Jacinto basins, the physical dimensions of reservoirs, pumps, and related structures necessary to achieve this are so large as to be impractical. That may or may not be the case, however, in basins in drier parts of the state, especially with respect to subsistence and dry period base flows. Furthermore, it is unclear as to what exactly would be learned by analyzing this maximum infrastructure scenario with regard to future streamflow characteristics. It has to be assumed that any set of recommended instream environmental flow requirements would already incorporate those flow components (magnitudes and frequencies) that have been generally agreed upon as being important for supporting a sound ecological environment. So, by definition, future flow conditions with these environmental flow requirements implemented would have to be characterized by the occurrence of these specific flow magnitudes at their designated frequencies in order for diversion or impoundment under new permits to be allowed. It seems

[2] It should be recognized that the WAMs modified through the regional planning process to reflect implementation of future water supply development projects may not contain the same assumptions regarding existing water rights and prior appropriation as the WAMs currently used by the TCEQ for permitting purposes.

that the real issue is whether the recommended environmental flow components themselves reflect the proper magnitudes and frequencies to achieve their designated objectives, and this, of course, is the crux of the difficulties in identifying an adequate environmental flow regime as defined by SB 3.

An important aspect of the multi-tiered structure for a recommended environmental flow regime as described above and depicted in Figure 1 is the attainment frequency, or range of attainment frequencies, at which each of the different flow components should occur in order to support a sound ecological environment. Such frequencies, or range of frequencies, for the various flow components can be expressed as the percent of time certain flow magnitudes are expected to be equaled or exceeded during certain time periods (e.g., monthly, seasonally or annually) with existing and proposed (new water right permits or amendments) water use activities in place and operating. In the context of an environmental flow regime or standard, it is anticipated that attainment frequency guidelines would most likely be applicable to base flows, high pulse flows and/or overbank flows. The need to achieve minimum subsistence flows generally would apply all of the time to the extent such flows are available under existing conditions; thus, an attainment frequency for a particular subsistence flow probably is not relevant. Information in the SAC's 2009 Instream Flow report (SAC, 2009a) addresses attainment frequencies for high flow pulses and overbank events. For base flows, in the absence of specific information describing biological-flow relationships and the flows necessary to support existing ecosystems, a preliminary estimate of the attainment frequency guidelines may be informed by consideration of the historical occurrence of the recommended flow magnitudes for those systems considered to be characterized by a sound ecological environment. This approach pre-supposes that historical flow frequencies for these components of the flow regime represent what have likely been more than adequate to support a sound ecological environment even though specific biological data may not have yet been identified or developed to support this hypothesis. This appears to be a reasonably valid approach for proceeding with the development of appropriate environmental flow requirements pursuant to SB 3; although, there certainly could be other means for considering attainment frequencies for base flows.

Conceptual Model for Flow Regime Application

In this section is outlined a conceptual model describing the process by which the BBASC can apply an environmental flow regime as developed by the BBEST in the formulation of an environmental flow standard(s) in accordance with the provisions of SB 3. At the outset, it is important to note that the array of flow components comprising the environmental flow regime does not necessarily represent a flow standard(s). It may be desirable to simplify the articulation of flow standards to provide wider coverage over larger geographical areas than the single points in a stream upon which individual flow regimes were derived, to be more applicable cumulatively to multiple organisms important to the river ecosystem, or to incorporate information regarding existing or future water diversions and needs. In essence, the environmental flow regime that is produced by a HEFR-type analysis using a record of daily flows and perhaps scientific results relating elements of the ecosystem to streamflow must be further digested to formulate flow standards. It is envisioned that this digestion will be iterative, in which (1) various strategies and magnitudes of draft standards are formulated, incorporating aggregate ecological and hydrological results and recommended environmental flow regime(s) from the BBEST; (2) draft standards are tested by hydrological and water availability modeling under existing and/or projected future hydrological modifications and water use activities and needs; and (3) the level of success is

evaluated of balancing the achievement of a "sound ecological environment" with the satisfaction of existing and/or future human water uses and needs.

Specific steps that could be followed by the BBASC are described below. As with the analyses undertaken by the BBEST, some of these steps are iterative and may be cycled several times as refinements and adjustments are made by the BBASC to candidate environmental flow standards.

Step 1 Using existing water availability models (WAMs) from the TCEQ with all existing water rights fully engaged as authorized (Run 3) and/or as currently utilized (Run 8), analyze the simulated flows from the WAMs to determine attainment frequencies for the specific subsistence/base flows, high-flow pulses, and overbank flows incorporated in proposed environmental flow regimes recommended by the BBEST.

Consideration of information describing the attainment frequencies of the different components of a flow regime under conditions reflecting existing water rights authorizations and/or utilization will be important to establish a baseline from which further evaluations of recommended attainment frequencies can be undertaken. It is recognized that the initial a priori definition of appropriate attainment frequencies will likely be very difficult because of the lack of scientific studies of site-specific environmental flow requirements, and hence, will likely be founded to a large extent on professional judgment and experience, taking into consideration historical attainment frequencies where sound ecological conditions currently exist. Input from the BBEST could be very helpful in this task. Quantifying the attainment frequencies of the different flow components under conditions reflecting existing water rights authorizations and/or utilization will, at a minimum, provide a starting point for evaluating the adequacy of these projected attainment frequencies and provide direction on the significance of deviating from the recommended attainment frequencies. The difficulty of representing daily varying flows and episodic events in a WAM monthly simulation must be accommodated in interpreting these model results.

Step 2 Use the appropriate water availability model (WAM) datasets developed for regional water supply planning in the basin of interest to assess the potential impacts of a proposed environmental flow regime or flow standard or set of such regimes or standards on available surface water supplies and future flow conditions for one or more assumed future water demand and/or supply scenarios.

As with similar analyses that may have been employed by the BBEST, this step will require some assumptions regarding exercise of existing rights and future water-supply infrastructure. These assumptions should be clearly stated and documented. The most reasonable future water supply development scenario is likely to be one that encompasses the recommended water supply strategies adopted through the regional water supply planning process as encompassed in the 2007 State Water Plan. Information from this step will be useful to the BBASC for evaluating the impacts of proposed environmental flow requirements on the ability to satisfy future human water needs and for assessing the effectiveness of the proposed environmental flow standards for supporting a sound ecological environment.

The WAMs modified through the regional planning process to reflect implementation of future water supply development projects may not contain the same assumptions regarding existing water rights and prior appropriation as the WAMs currently used by the TCEQ for permitting purposes, as noted earlier.

Hence, it is important to understand these assumptions when evaluating results from the planning models. Also, application of WRAP with a monthly time step requires that the daily and event-based environmental flow restrictions be expressed as monthly flow quantities, which results in only an approximation of the environmental flow restrictions and potentially produces simulated flows that may not be fully representative of actual conditions.

Step 3 Review the BBEST's environmental flow analyses and environmental flow regime recommendations and consider them in conjunction with other factors, including the present and future needs for water for other uses, so as to develop environmental flow standards and strategies to implement the standards.

This step is the basic foundation for the work of the BBASC. Information from Steps 1 and 2 provide input to this effort, with iterations between Steps 2 and 3 providing refinements and adjustments to proposed environmental flow standards. Interaction and consultation with the BBEST during this evaluation could maximize the opportunity to meet the full SB3 objectives.

Step 4 Finalize the BBASC recommendations regarding environmental flow standards and strategies to meet these standards, and submit these to the TCEQ and the EFAG. Again, all assumptions used must be fully documented.

The environmental flow standards recommendations will depend both on the analyses described in Steps 1 through 3 above *and* on consideration and evaluation of what strategies might be used to ensure that achievement of the recommended flow standards is not impaired. SB 3 does not set out specific terms for the development of strategies, so the BBASCs have broad leeway to examine potential avenues for implementing flow standards. For example, they could agree to analyze how changes in operation of major reservoirs, dry-year leasing of water rights, dedication of return flows, or other strategies can be used to help meet standards. Clearly, SB 3 does not give BBASCs authority to make binding recommendations with respect to strategies; but strategy development is an important part of the charge to provide the end product of a set of recommended environmental flow standards and strategies to meet the flow standards.

The SB 3 process of course does not end here. The TCEQ promulgates environmental flow standards through a rule-making process and determines applicable set-asides after considering the environmental flow regimes recommended by the BBEST and the environmental flow standards and strategies to meet the standards developed by the BBASCs, EFAG comments, information provided by the SAC and other interested parties, public comment, and other factors relevant to environmental flow issues including economic impacts, human and other competing water needs, and river basin and bay system characteristics.

TCEQ then evaluates future water right permit applications taking into consideration the adopted environmental flow standards and set-asides. Individual permit restrictions are formulated as required to ensure that associated permits do not impair the ability to satisfy the adopted environmental flow standards and set-asides. *Permit restrictions* (synonymous, in this context, with *flow restrictions* or *permit conditions*) are the set of rules defining when diversions and/or impoundment of streamflows are allowed and authorized under a specific water right permit. Historically, this has been a set of minimum flows specified in a water right permit for different months or seasons (such as those derived with the

Lyons Method [Bounds and Lyons, 1979]) or for different hydrologic conditions (such as those based on the Consensus Planning Criteria [TWDB, 1997]) below which flows cannot be diverted and/or impounded. Recommended attainment frequency guidelines for specific flow values are not necessarily stipulated, nor determined, though they could be.

Permit restrictions designed to protect the environment pursuant to SB 3 are generally expected to be tied to actual instream flow values though applicable permit restrictions during wet, average, and dry conditions and may vary based on triggers associated with reservoir storage, cumulative flows, drought indices, and/or other factors. With the adoption of environmental flow standards by the TCEQ, the objective of permit restrictions as formulated and implemented by the TCEQ will be to ensure that the ability to satisfy the essential elements of the environmental flow standards is not impaired by the permit itself. In this regard, it is anticipated that the level of complexity incorporated into permit restrictions may vary in relation to the size of a permit authorization (diversion rate, annual diversion amount, and/or on-stream impoundment capacity) and the degree to which said authorization could potentially impact streamflows relative to environmental flow requirements. The permit restrictions would therefore conform with some translation of the flow requirements of the adopted environmental flow standards, but may not necessarily incorporate all aspects for each type of permit. The exact nature of how the adopted flow standards will be translated into specific permit conditions is unknown at this time, but will have to be addressed by the TCEQ.

One last element of the overall SB 3 environmental flow process relates to the environmental flow "set-aside". As defined by SB 3, the set-aside is "an amount of unappropriated water, if available, to be set aside to satisfy the environmental flow standards to the maximum extent reasonable when considering human water needs". It is further noted that the TCEQ may not issue a new appropriation or an amendment that increases the amount of water authorized to be stored, taken or diverted if such issuance would impair an environmental flow set-aside. As indicated, the environmental flow set-aside relates to a specific amount of unappropriated water at a specific location that apparently is intended to protect and reserve water specifically for ensuring that new permits do not impair the ability to satisfy the adopted environmental flow standards. In any event, special conditions would likely be included in any new permit or amendment that effectively would ensure that ability to satisfy the adopted environmental flow standards would not be impaired due to the permit or amendment.

Issues Discussion

Lack of Sufficient Site-Specific Data and Analyses – Use of Statistical Flow Parameters - As the SB 3 environmental flow process has initially has been undertaken for the Sabine/Neches and Trinity/San Jacinto basins and their associated bay and estuarine systems, and as the SAC has deliberated how to facilitate this process, issues have arisen with regard to the lack of sufficient site-specific scientific data and analyses describing the essential relationships between environmental flows and the actual needs of aquatic organisms in those systems. In some situations, relationships derived from studies of similar streams and rivers in Texas that share many of the same environmental features and species as the target segments can be used, along with basic ecological principles, to make judgments about ecological responses to flows. Furthermore, as a surrogate for such information, statistical flow parameters based on historical hydrologic conditions have been examined as a default for establishing environmental flow requirements in streams with insufficient data, once the judgment is made that these systems currently reflect a sound ecological environment. The premise is that if a sufficiently close representation of key

elements of the historical hydrology is maintained, then a reasonable approximation of the historical sound ecological environment is likely to also be maintained, while at the same time making available water for development. In this regard, any recommendations for environmental flow requirements replicating these historical flow parameters (and their historical frequencies of occurrence) logically might be considered an approximation (arguably the *maximum*) of the flow conditions needed to continue to support a sound ecological environment as available water resources are being developed. The presumption is that different quantities of flow, different frequencies of occurrence, or different seasonal distribution patterns of recommended flows may also be adequate. Depending on how the parameters are chosen and calculated, various components of the overall environmental flow matrix could be altered, perhaps significantly, from the historical period of record and still yield a sound ecological environment.

Effect of Changing Conditions - In addition, it is important to recognize that, because conditions in some watersheds have changed over the historical period, there is no guarantee that the biological response to a repeat of historical hydrologic conditions (say the drought of record, for example) would be essentially the same as it was many decades ago. The presumption is that some lesser quantities of flow or some lesser frequency of occurrence than were experienced historically may still be adequate to sustain a sound ecological environment. As discussed further below, as a result of more extensive future utilization of existing water rights that are not subject to newly adopted environmental flow standards, for the vast majority of watersheds, flows are likely to be significantly reduced below historical levels. Implementation of environmental flow standards and application of these standards to new permits for storage or diversion, along with market approaches for satisfying environmental flow standards required by SB 3, will minimize additional changes to various aspects of existing flow conditions. With the continuing effort to derive meaningful information describing important relationships between environmental flows and the actual needs of aquatic organisms in these systems, it is anticipated that hydrology-based estimates of environmental flow requirements likely will be refined in the future. SB 3 recognizes this possibility through its adaptive management provisions.

Expected Future Conditions - A key issue in developing environmental flow standards that will meet the SB 3 statutory tests is what future demands and supply alternatives might be assumed by the BBASCs for purposes of balancing water needs for satisfying environmental flow requirements with the water needs for other uses, including providing sufficient water to meet existing and future human water needs. In this regard, future conditions relate directly to projected future water demands and options for meeting those demands[3]. The ongoing regional and state water planning process to meet future water demands on a decade-by-decade basis over the next 50 years is a logical place to look for such information, though it is important to remember that these plans are currently being revised. Various water development projects are described, with a schedule for their proposed implementation by decade, in the TWDB's 2007 State Water Plan. As a starting point for the balancing process, it would seem appropriate for the BBASCs to use one or more of these future decadal conditions as the basis for establishing future human water needs (demands) and the attendant new surface water development projects required to meet those

[3] The SB3 environmental flow requirements will only apply to permits and permit amendments for new appropriations and authorizations to store, take or divert surface water that are issued by the TCEQ after the date the relevant standards are adopted by TCEQ. Permits and permit amendments for new appropriations and authorizations to store, take or divert surface water that are issued after September 1, 2007 but before the flow standards are adopted by TCEQ are, however, subject to a provision that allows the environmental flow conditions included in those permits to be adjusted up by a certain amount (12.5%). As stipulated in SB3, the priority date for an environmental flow set-aside, if any, is the date that the BBEST submits its recommendations.

needs. Stakeholders might determine that specific new projects recommended in the plans should be evaluated in light of any proposed environmental flow regime recommendations or standards, which could provide insights about the compatibility or feasibility of various projects with recommended flow regimes or standards.

Which future decade to use as the basis for evaluating the balance between dedicating water for environmental flows and for meeting human needs will be a decision that will have to be addressed by the BBASCs depending on basin-specific conditions. Obviously human needs are less in the earlier future decades than they are projected to be in 50 years, which translates to more surface water being available for other uses, including environmental flows, in say, the next 10 to 20 years. Adaptive management already is contemplated in SB3 as a means for modifying environmental flow requirements as new data and information become available after the initial environmental flow standards are adopted, so this same review process may also be employed to ensure effective balancing between environmental flow and human needs in the future.

As noted earlier, existing WAM datasets maintained by the TCEQ for all river basins in the state can provide (possibly with some modifications to reflect actual return flow conditions) useful tools for evaluating surface water supplies for satisfying existing water rights and for meeting future needs for human demands and environmental flows. Using the WAMs in this fashion would involve modifying the existing datasets to include some or all of the anticipated future water development projects with appropriate provisions incorporated to ensure that the ability to satisfy the proposed environmental flow requirements would not be impaired by the projects themselves. Again, most, if not all, of the proposed major surface water development projects already have been represented in the WAMs through the regional planning process, although none with any of the environmental flow requirements that are likely to emerge from the SB 3 process (these would have to be added). Still, the means readily exists, using WRAP and the WAM datasets for performing at least the initial evaluation of the availability of surface water for satisfying existing and some projection of future human water needs and proposed SB3 environmental flow requirements.

Finally, the WAM datasets could also be used to evaluate various scenarios to help identify strategies for meeting environmental flow standards, as the stakeholder committees may chose to look at more than one future scenario as part of their work. It would make sense for the BBESTs to provide information, perspective, and assistance to their BBSAC as strategies are evaluated. These model results with the instream environmental flow requirements implemented would be especially useful for describing future freshwater inflows to the state's bay and estuary systems as these inflows may be modified by future water development projects and/or environmental flow standards and strategies.

Observations and Conclusions

1) Permit restrictions need not be as complex as the underlying environmental flow regime or flow standard themselves. For example, for a relatively small new appropriation that is likely to not appreciably alter normal or above-normal streamflows, the requirement for high-flow pulses or overbanking flows would not be necessary.

2) The approach for defining attainment frequency guidelines for base flows based on historical flow frequencies offers a straightforward and practicable method. However, it is important to

recognize that this approach only provides a starting point, because it does not directly consider actual requirements of the stream ecosystem. The BBEST should employ the various overlay methodologies to inform appropriate attainment frequencies until such time as more appropriate and specific information describing biological-flow relationships and the flows necessary to support existing ecosystems becomes available.

3) It is important to further recognize that attainment frequency guidelines less than those based on historical flows may, in fact, support a sound ecological environment and should be considered when sufficiently supported by professional judgment and experience. Similarly, in some watersheds, it may be possible that attainment frequencies based solely on historical flows may be judged to not be adequate to support a sound ecological environment.

4) The question of future infrastructure is still manifest if a time series of future hydrology is desired. Some level of expected infrastructure, consistent with meeting the desired future water needs for other (human) uses, must be assumed to provide a meaningful analysis and evaluation of instream flows with specific environmental flow regimes or standards imposed. Infrastructure associated with year-2060 proposed surface water development projects included in the 2007 State Water Plan is one option for estimating future conditions. However, to the extent that an assumed level of infrastructure is relied upon in evaluating the adequacy of a recommended flow regime or standard, the environmental flow standard should reflect that assumption in order to ensure that the assumption is not violated in applying the standard.

5) Adaptive management with regard to environmental flow requirements must be planned for and incorporated as an integral part of future environmental flow analyses. SB3 contains provisions for such continuing adaptive management activities after the environmental flow standards and set-asides are initially adopted by the TCEQ and includes a mechanism for adjusting the conditions requiring protection of instream flows or freshwater inflows included in new individual water right permits (maximum increase of 12.5% of the annualized amount required for protection of instream flows or freshwater inflows for permits issued after September 1, 2007). Each BBASC, with assistance from its associated BBEST, is required to prepare and submit to the EFAG for approval a work plan that includes the following:

    - Program for the review of environmental flow analyses, flow regimes, flow standards and strategies, and set-asides at least once every 10 years,
    - Program for basin and bay specific monitoring, studies, and activities, and
    - Schedule for continuing the validation or refinement of environmental flow analyses, flow regimes, flow standards and strategies, and set-asides.

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